Zoologica, Vol. XII, No. 5

NOTES ON THE GILL-FINNED GOBY*

Bathygobius soporator (Cuvier and Valenciennes)

With an Explanation of the Specialized Pectoral Fin.

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OUTLINE

Introduction: For a space of six weeks from July to August, 1930, my deep-sea trawling engine was out of commission and my bathypelagic work temporarily at a standstill. The fish nearest at hand was *Bathygobius soporator* which was to be found in every tide-pool on the shores of Nonsuch.

I collected a few, and studied them both in aquaria and in their own haunts. The following notes sum up my observations on this most interesting fish.

Name and History: In 1837 Cuvier and Valenciennes gave the name *Gobius soporator* to a fish which M. Achard had brought from the island of Martinique in the West Indies. Forty-one years later Bleeker considered that this species was worthy of separate generic distinction and called it *Bathygobius*. A less appropriate title could hardly be imagined for this inhabitant of tide-pools and other shallow waters. The specific name is a Latinized translation of the term by which the native West Indians know this species.

*Contribution, New York Zoological Society Department of Tropical Research, No. 360.

In Bermuda, in common with several other related species, this goby is called, for no apparent reason, Molly Miller, Sheep's head Molly Miller and Black Joe. Elsewhere it is known as the Sleeper, Babosa, Amoreia, Mapo, Caiman, Oopu, Too-goo, Silk-finned Goby, etc.

Field Characters: This is a medium-sized Goby, with united ventral fins free from the abdomen; head depressed, body compressed posteriorly; *pectoral fins with upper rays free and filamentous.*

General Range: Reported to be cosmopolitan in the tropics, but intensive study will probably show considerable geographical speciation. In the western Atlantic it has been recorded from Bermuda, Charleston, Florida to Colon and the West Indies, south to Bahia and Rio Janeiro.

Occurrence in Bermuda: This is the commonest goby in the infrequent tide-pools, found sometimes on sand but generally on rocks. At low tide on August 20, 1930, a census of all tide-pools on the shores of Nonsuch showed one hundred and twenty-six fish; probably well below the actual number. In an isolated tide-pool on Cock Rock on August 24, there were twelve of these gobies, four of them over three inches in length. In shallow water observing from the diving helmet, I have seen this species as deep as two fathoms on sand.

Sociability: There is no schooling or concentrating of these fish other than the normal association which of necessity results from such a localized habitat. From three to seven fish are usually found in a tide-pool of good size, seldom more than one large one. Several times (six to be exact) I have changed marked individuals from one tide-pool to another, many yards away, and five out of the six times the transferred fish were found next day in their original pools. So there is apparently a definite habitat selection and a decided preference for a certain chosen spot. When crowded in an aquarium they will nip one another's tails, but I have never seen any evidence of serious attack in undisturbed individuals.

Viability: The viability of these gobies is remarkable, although only what might be expected from their habitat in life. A newly caught goby 43 mm. in standard length displaced 2 cc. of water. It was placed in a glass dish holding 50 cc. of salt water with a surface exposure of 60 by 90 mm., where it lived in apparently normal strength and activity for six full days. It then collapsed and could scarcely move or turn over. So

I removed it and found that the water had evaporated to 21 cc. At first the water barely covered the fish, while on the last day or two most of its back was out of water. The fish revived in a few minutes in a large aquarium.

Fresh water seems to make no difference to this fish. After three days in fresh water with only slight aeration, individuals of this species showed no symptoms of discomfort. The rate of breathing was quite normal.

One of my gobies recovered full health after three hours of accidental drying on the dust of a cement floor, and after its eyes, gills and skin were thoroughly dry and coated with all manner of débris.

General Form : The first glance shows that this goby is not built for continued speed or sustained activity of any kind. It has relinquished its ancestral heritage of motion in three planes of space and has struck bottom and remained there, paying the penalty of an unlovely rebalancing of its whole being and the resulting heaviness of general structure and form which characterizes terrestrial creatures as compared with those which inhabit the water and the air.

The general lateral outline of the body is as nearly an elongated rectangle as a fish can show. Anteriorly the body appears heavy and robust. The back slopes very slightly downward to the tail and the ventral profile is almost flat, a very evident adaptation for resting on the bottom. The head is rounded, the snout short and curved, merging halfway into the thick flat lips. The general lateral appearance is of a clumsy, awkward, inept species of fish.

The top view shows more shapeliness, the anterior half still thick and heavy, but the posterior tapering rapidly. The two views taken together reveal a vivid relation to the dominant activities in a two-plane life. There is little provision for up and down movements, but abundant adaptation in the narrow, laterally pliable peduncle, for quick left or right, forward or back twists, turns or darts.

From the top, the resemblance of the head to that of a frog is striking; the broad rounded mouth, the bulging eyes and the turgid jowls. The greatly swollen character of the opercles appears to be due to two dominant causes, first the necessity of lateral, not ventral movements in respiration, and the second, the need for an unusually strong, hence thick, operative musculature. These fish, in having to contend

with the smashing power of the waves and the tremendous pull and push of surging waters, could not avoid damage to any external delicate organs. The mouth is hence protected by great fleshy, yet deeply socketed lips. The eternal hydraulic pump which means life itself, avoids injury from the risks which stress of external force induces, by an over development of opercular muscles.

Size and Weight: Six inches is the maximum length of this species, and half that extent is a much more common size of adult individuals.

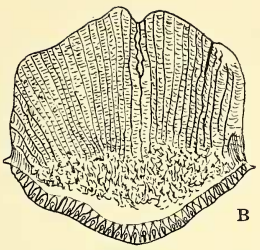
31 mm. (33 per cent)	.....	.8 grams (6 per cent)
51 mm. (55 per cent)	.....	2.5 grams (18 per cent)
79 mm. (85 per cent)	.....	8. grams (60 per cent)
93 mm. (100 per cent)	.....	13.5 grams (100 per cent)

The above table shows the relative percentages of length and weight.

Scalation: In a goby of 21 mm. standard length the entire body is covered with scales except the head, the nape back to near the first dorsal, and the area around and behind the ventrals as far back as the anus. The scales bordering the clear nuchal area and between the pectorals and ventrals are very small, but normal in structure and in their moderately deciduous character. These soon give place to scales of average size. From the vertical of the first dorsal the scales increase in size steadily toward the tail, the largest being on the sides of the caudal peduncle.

In the 21 mm. specimen there are fourteen rows at the vertical of the first dorsal, and six rows at the tail. On one side of the fish I count 665 scales. Doubling this and including seventeen median ones, we have a total of 1347 scales on the entire fish. Their arrangement in longitudinal rows is as follows:

1st row, nape to 1st D—24.
2nd row, nape, nearly to end of 1st D—30.
3rd row, nape, to end of 1st D—44.
4th row, nape to caudal—43.
Remainder of nape scales—23.
5th row, end of nape to end of 2nd D—30.
6th row, end of nape almost to caudal—36.
7th row, top of P to C—36.
8th row, midline, P to C—35.



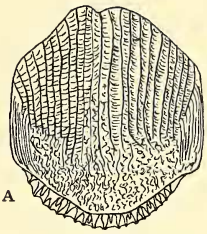


Fig. 12. Typical scales of *Bathygobius soporator*. A—Midline scale of a 31 mm. fish; B—Midline scale of a 72 mm. fish.

9th row, P to C—38.
10th row, P almost to C—33.
11th row, P to caudal peduncle—55.
12th row, P to C—27.
Ventral area of small scales—180.
13th row, end of small scales to posterior end of V—17.
14th row, end of small scales to anterior end of V—12.
D line on caudal peduncle—7.
V line on caudal peduncle—10.

The scales are strongly ctenoid, probably a valuable asset in aiding the fish to retain its hold and resist the stress of breaking waves. They are remarkably uniform and vary chiefly in relative size and slightly in shape.

For illustration I have chosen a scale from two individuals, taken in each case from the 8th or mid-line row, the seventh scale from the caudal end. A is from a fish of 31 mm. standard length, B from one 72 mm. long.

	Standard Length	Scale Length	Scale Width	Length Ctenoid Spines
Specimen A.....	31 mm.	1.4 mm.	1.2 mm.	41 mm.
Specimen B.....	72 mm.	3.0 mm.	2.9 mm.	22 mm.

Specimen A: The exposed or posterior edge of the scale slopes backward 35° evenly above and below from an obtuse central angle. Along this side are 40 slender sharp teeth, with stout bases, pointing at right angles to their individual bases. An inferior tissue of skin reaches to their tips. The hidden or anterior edge of the scale has the same angles as the posterior edge but the center has a slight notch. The dorsal and ventral contour between the slopes of the other edges are

horizontal. From the anterior edge to half-way along the dorsal and ventral planes there extend twenty-three radii, horizontal centrally, but becoming slightly oblique above and below. These reach about three-fifths over the entire scale, giving place to an area of broken lines and irregular markings. Between each of the transverse lines are stout, fine, concave circuli, none of these quite reaching the radii themselves. On mid-scale there are about thirty of these before they dissolve into irregular hieroglyphics. Beyond the last dorsal and ventral transverse markings, the short circuli become lengthened into about ten lines which parallel the outer border of the scale.

Specimen B: The scale is much more rounded posteriorly, but with the flat dorsal and ventral contour and the anterior angles and notch as in Specimen A. The spines have increased to 74, and are longer and more slender. The increase has been by the intercalation of small spines between the larger ones, which seem to have no definite basal attachment. The larger teeth, whose bases connect with one another, represent the original ones, as they are forty-four in number.

The radii have increased to thirty-six, but nine of these are imperfect, absent at one or the other end. The circuli have remained as fine as before, but about doubled in number. The transparent skin on the entire exposed portion, about one-half of the whole scale, is sparsely covered with fine black chromatophores.

In the nuchal mid-line scales, lying just before the 1st D, the posterior line of spines is altogether lacking, the entire scale being occupied by about twenty radii and the intervening circuli.

On the side of the fish close behind the pectoral, the scales are much reduced in size, and the teeth are cut down to 21, a small number but all of full size and normal structure.

Pigmentation: The basis of the pigmentation in this goby is quite simple. A low power lens shows the transparent dermis of the living fish covered more or less solidly with a multitude of small, greyish-white chromatophores, circular, with fairly regular circumference. In the center of each is a small black dot—round and dense. The darkening of the light ground color is caused by the dendritic enlargement of this central black chromatophore. On many parts of the body the heart of the black spot is intense blue, and this is strong enough to show up brightly in certain liveries. When orange appears it is in the form

of very small round spots in the white border. If the black remains contracted and the orange chromatophores expand, the general effect is of a solid orange or golden area. In one dark phase the dominant color is green and this appears to result from a juxtaposition of the blue and the golden. After death the separate character of the large white areas is lost.

Usually, when the dark cells expand, they become dendritic, but on the cheeks they may enlarge into curious square or pentagonal outlines and remain firm all along the contours.

Color: Few fish show such radical color changes as the gobies and I believe it would be possible to make half a hundred slightly different paintings of a single individual. But there is an average mean—a usual livery which may be used as the basis of description. It is difficult of exact description, for the instant one of these gobies is caught or killed the entire pattern and visible pigmentation changes. The only safe way is to attract all the gobies of pool after pool with a bait of crushed chitons and then with a short focus glass to watch and record and compare every detail of the coloration.

In Bermuda specimens there are four well marked extremes of pattern and color, and these may be described and defined as follows:

Color phase A—Normal—Black and White.

Color phase B—Fear—Blue-Spotted, Dark Green.

Color phase C—Nocturnal—Banded.

Color phase D—Sand—White.

Color phase A, Normal: I call this the normal phase because it is the usual livery of the undisturbed gobies in the rocky tide-pools (not on the sand). In an aquarium, after a day or two, when they have become used to the new conditions they return to at least an approximation of this coloring.

In this phase there are about ten narrow lines of white, and ten of dusky gold extending down the whole body. The white is rather less connected but to the unaided eye, dominates the gold. This is because the gold is oxydized with very dilute, dendritic, brown chromatophores, which deaden the yellow and make it appear dark. The purity and sheen of the white produces a curious appearance of a series of ribs in high relief.

On this lateral background are three linear series of large dark

blotches, cut into more or less oval shapes by the white longitudinal lines. These gross markings extend from the back two-thirds down the sides, and on the peduncle become reduced to five or six round, dusky spots.

This pattern and coloring are all derived from the dermis. Aside from a few, small, scattered black dots, the scales are colorless. When a patch of these is removed the important chromatophores appear. The golden are interspersed with brown ones, the white are strengthened by a substratum of solid silver.

On the opercles the dark chromatophores are dominant, forming a solid background for numerous, small, round, white spots. There are three, large but indistinct dark blotches on the preopercle, and in some cases an irregular, dark, pale-bordered band extends from the eye to the upper limb of the pectoral.

The fins all show more or less distinct, but broken, bands of black and white, the anterior spine of the first and second dorsal being always sharply marked. Dark blotches may come and go on the lower cheeks and on the pectoral bases.

Color phase B—Fear: This is essentially a dark green pattern, and is assumed at moments of extreme fear. A goby usually changes very suddenly into this when dipped up roughly from its pool, or, when cornered, it attempts to leap from one pool to another. On making its escape after being thoroughly alarmed, the fish invariably seeks concealment in a crevice, a dark hollow, or among and in dark green seaweed. Hence this sudden shift of color is explicable by the speed and character of the change in environmental background. The shift is almost instantaneous, but the reverse is very gradual, probably from the slow dying down of the more violent emotion than from any physiological cause.

The general color of the head, body and fins is dark green, the head decidedly darker, while both dorsal fins show a wide margin of yellow. Over the head and body there appears an abundant scattering of small blue dots.

Color phase C—Nocturnal: The most common pattern and color assumed at night is a banded one wholly unlike any other extreme phase, although often shown in transitory light tints. It is frequently assumed when oxygen is lacking and the fish is feeling the need of fresh water. Looked at from above, the nape and snout are black, the rest of the head back to the first dorsal seal brown; then another black band and a brown

Fig. 11. Color phases of *Bathygobius soporator*. A—Normal; B—Fear; C—Nocturnal; D—Sand; E—Front view of goby supported by the vacuum formed by the ventral fins. From a painting by Else Bostelmann.

band of equal width, followed by a narrow black, a white, and a brown band on the peduncle. The two broad black bands are bordered with a wide margin of white.

Color phase D—Sand: When on hot, sunlit sand, the gobies change again, this time bleaching out almost every dark marking, except very faint ones on the fins. When completely sand adapted the fish are absolutely invisible, their sessile position avoiding shadows, and their color exactly that of the grains of sand.

Fins: This fish, like most gobies is generously provided with fins, the eight separate structures being supported by one hundred and ten spines and rays. Unusual specialization is evident only in the four paired fins, the upper rays of the pectorals being free, delicate and soft, and the ventrals being joined together in a vacuum-making cup—typical of many species of the family.

Elsewhere this goby seems to show considerable variation in fin rays, but in sixteen Bermuda individuals measuring from 20 to 70 mm. in length, there is only a single instance of variation. This is in a fish 55 mm. long, in which there is an additional superior caudal spine, making eight. The corresponding ventral element is represented only by a merest dot of bone.

The very consistent fin count in Bermuda specimens is as follows:

Dorsal VI—I, 10
Anal I, 9
Caudal VII—17—VII
Pectoral 20
Ventral I, 5

Respiration: When the goby is resting quietly and breathing normally, the respirations number about two every second. The movement brings into play all the bones of the mouth, jaws and throat. The mouth never closes, in fact its entire movement is very slight, much less than that in the average fish. The mouth opens, draws in water, then partly closes and the internal, labial, membrane veils close together while the opercles at the rear spread out laterally and draw the water back simultaneously with the closing down of the pliant branchiostegals over the skin back of the pectorals; the movements follow one another rapidly and smoothly.

Ordinarily this is the only respiratory movement, but when the

oxygen content gets low, in an aquarium or in an isolated, high-set, super-heated tide-pool, then the second line of breathing comes into play —the upper fourth of the pectorals, bearing the long, webless, soft rays and raylets, begins to wave back and forth. They move synchronously and are timed exactly to take advantage of the stream of water coming from the gill-openings. As the branchiostegals close down, ejecting the last mouthful of water, the pectoral gills move forward. When this process is in full swing the pectoral fins as a whole are raised and spread out laterally, but only the upper part—no more than a fourth of the entire fin, is in motion. I have seen it in play when the pectoral fins had to keep firm grip on a rock, and under such conditions the mobility of muscular movement and the sharp distinction between the actively waving part and the immobile lower section was very sharp and striking. The number of the free rays varies, but there may be as many as fourteen undivided secondary branches. Curiously enough these rays are less sensitive to touch than are the other, less specialized rays. Neither from direct observation in life, nor in microscopic observation do I find any confirmation of the tactile function which has been suggested by some authors—". . . les rayons supérieurs devenus crinoïdes servent d'organes du tact."

The gill-openings are admirably adapted for functioning in a tide-pool. Their complete opening is about the width of the muscular base of the pectoral and these apertures are placed close to that fin. As these fins are wholly lateral, it follows that the fish can flatten its head and thoracic region on the bottom of the pool without interfering with the full respiratory action.

Instead of simple tips to the rays of the remaining fins, we find that there are a multitude. To take the first coarse divisions, we find that a total of 89 fin rays shows a division into 456 tips. Individual fins are as follows:

Pectoral: 21 rays and 92 tips.
Ventral: 5 rays and 43 tips.
Second dorsal: 9½ rays and 41 tips.
Anal: 9½ rays and 54 tips.
Caudal: 17 rays and 91 tips.

Each of these tips has in turn a more minute subdivision into 4 to 8, and taking 6 as a fair average, we have 2736 distal, fingerlike, fleshy,